UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

IN RE AUTOHOP LITIGATION This Document Relates To: DISH Network L.L.C., 12 Civ. 4155 (LTS)(KNF)	12 Civ. 4155 (LTS) (KNF) **DECLARATION OF PAUL HOROWITZ ON THE OPERATION AND TECHNOLOGY OF DISH NETWORK'S "HOPPER"** **REDACTED PUBLIC FILING, ORIGINAL FILED UNDER SEAL**

I, Paul Horowitz, declare:

1. I am a Research Professor of Physics and of Electrical Engineering at Harvard University, where I perform and supervise experimental research, and develop new courses in electronic circuit design. Additional career details can be found in Section III, and in the attached Curriculum Vitae.

I. Scope of This Declaration

2. I have been asked by attorneys for DISH Network ("DISH") to set down in this declaration a description of the operation of the "Hopper" Satellite TV receiver and DVR (Digital Video Recorder), both from the user's point of view, and from the technical point of view of what happens "under the hood." Of particular interest are the features known as PrimeTime Anytime ("PTAT") and AutoHop. I have been asked, also, to describe the operation of home recording devices in general, and other currently available "set-top-box" digital video recorders ("STB-DVR"), for example the well-known TiVo brand, or those provided with a cable television subscription. Further, I have been asked to include tutorial material helpful in understanding the technical aspects involved.

3. In the following sections I have prefaced these topics with background information, in the form of a tutorial on television (audio and video), starting with the capture of the moving image and sound, its conversion to electronic signals, and their subsequent storage, transmission, and reproduction. The discussion includes the traditional "analog" methods of video and audio, and the contemporary "digital" methods that dominate the technology of audio, video, and television.

4. If asked at hearings or trial, I am prepared to explain in detail, with appropriate visual aids, background information on satellite, cable, and over-the-air (OTA) video systems, including audio and video formats (both digital and analog); compression, modulation, transmission, demodulation, and display; storage/retrieval

technologies; and details and comparison of the Hopper with analogous DVR systems. These may include, among other things, background information on electronic circuits, components, and systems in general, and audio/video technologies in particular. I am also prepared to testify on matters raised in cross-examination; to rebut, as necessary, matters raised (in reports, depositions, and/or court testimony) by plaintiff's experts; and to address other related matters raised at trial.

5. The following sections of this declaration are organized as follows:

and I have numbered the paragraphs for ease of reference.

II. Summary of Relevant Conclusions

6. Based upon the detailed discussion in §§IV VII of this declaration, the following is a summary of the relevant issues related to the PTAT and AutoHop features of DISH Network's Hopper and Joey satellite receiver set-top box (STB) and digital video recorder (DVR):

7. **PrimeTime Anytime™** (PTAT) is, in essence, a streamlined interface to "timer recording," a term describing the process by which a viewer schedules automatic recording of future television programs, for example by channel and time, or by selecting a future program (or programs) by name from a displayed program guide. PTAT allows the subscriber to designate daily recording of a chosen selection of the four major networks (ABC, CBS, Fox, NBC) during prime time, such recordings to be retained for a designated period selectable from two to eight days. Once PTAT has been enabled by the user, with selection of networks, choice of days to record, and duration of retention, the recording process is automated by the Hopper software.

8. PTAT is recorded at the subscriber's home, at airtime, from the linear satellite television signal that is being received normally. The recording is made on the Hopper's hard disk in a unique copy for the subscriber's later use only. It shares these attributes with any home DVR that the subscriber would program for timer recording of designated programs or channels at designated times.

9. PTAT is not "video-on-demand" (VOD): the latter consists of content (e.g., movies) that may never have been transmitted in normal "linear" fashion; or they may include television programs that were previously transmitted and have been stored by the provider for later viewing by individual subscribers, at their request. Both of these are to be distinguished from linear programming content that is sent to (and viewable by) subscribers at the scheduled time whether the subscriber viewed such content live, or directed recording of the programs (via PTAT or otherwise) during

linear transmission for viewing at a later time (time-shifting).

10. The ability to set a timer recording goes back to the original Sony Betamax video cassette recorder (VCR). The process has evolved with later generations of VCR, and further with digital video recorders (DVR) such as TiVo® that enable recording of multiple episodes (and even a full "season pass") of designated television program titles.

11. The **AutoHop**™ feature, when directed by the viewer, causes the Hopper or Joey to skip over commercial segments when playing back a PTAT recording. It is available beginning the day after the recording was made, and, when enabled, it causes software in the Hopper [redacted] By default the commercial segments are played normally; and in either case the PTAT recording itself is not altered in any way. Even with AutoHop enabled, if a viewer rewinds or fast-forwards into a commercial segment, it plays back normally.

12. The ability to fast-forward manually goes back to the original Sony Betamax, and has evolved with subsequent generations of VCRs and DVRs. Many VCRs and DVRs included "Skip Search" (or "Commercial Skip") features,[2] which advanced the tape by multiples of 30 seconds at the command of the viewer during playback. Some VCRs[3] went further, offering a feature that automatically detected and fast-forwarded over commercial segments. In essence, the AutoHop feature rep-

[redacted]

[2]See ¶¶100 101.
[3]See ¶¶102 103.

resents a refinement of this evolution, by automating and improving the 30-second skip function present on most DVRs.

III. Professional Background

13. My expertise in the field of electronics, computers, and communications includes some 50 years of electronic circuit design and implementation. In 1974 I originated an Electronics course at Harvard University, Physics 123, which continues to this day, and which is taught in the regular semester as well as in Harvard's Extension school and Summer school. Included in the course lectures are discussions of video (both analog and digital); transmission of signals by antennas, cable, and fiber optics; and the techniques of modulation, demodulation, and signal compression, to convey and store audio and video content.

14. A set of notes written originally for this course in 1974 was expanded (with co-author Winfield Hill) and published as *The Art of Electronics* by Cambridge University Press in 1980. That edition went through some 20 printings, adoptions by several technical book clubs, and translations into several languages, and it (and the companion *Laboratory Manual* co-authored with Ian Robinson) formed the basis for numerous copies of our electronics course; the textbook received much critical praise, and is generally accepted as an authoritative reference on electronic circuit design.[4] In 1989 an expanded second edition was published, again with co-author Hill, this time with an expanded *Student Manual* (with co-author Thomas Hayes). Translations of this edition have been published in German, French, Dutch, Chinese, Russian, Indonesian, and Polish, with additional foreign editions licensed or in progress. This text/reference covers electronics circuit design and operation broadly. It includes discussions of relevant topics, such as radiofrequency communications; transmission lines; modulation and demodulation; digital conversion, processing, storage, and transmission; and memory buffers. A greatly expanded third edition is in production.

15. In addition to electronics course work, I supervise graduate students whose

[4] It has the distinction of being one of the three circuit design texts included in IEEE Spectrum's "Treasured Textbooks (1940 1980)" (*Spectrum*, **40**, 7 (2003)).

work includes design and construction of electronic instrumentation. In that role, in addition to acting as informal consultant to other research groups at the University, I have designed numerous electronic circuits and instruments.

16. I also am the originator and co-supervisor of the Electronic Instrument Design Laboratory at Harvard University, run jointly by the department of Physics and the Division of Engineering and Applied Sciences. This laboratory provides circuit and instrument design, construction, and development services to research groups within the university.

17. Outside of my university duties I have designed electronic products for several commercial ventures. I have also led technical studies, and co-authored reports for various government entities as a member (since 1983) of a technical consulting group of academic scientists and technologists; these often involve issues of electronics in communications and instrumentation. In that role I have led some 20 technical studies, and coauthored over a hundred technical reports.

18. In my career I have designed and built literally hundreds of electronic circuits, broadly spanning the range from analog to digital, audio to radiofrequency, discrete to integrated to microprocessor. Over the years I have designed with vacuum tubes, transistors, and integrated circuits (from the earliest RTL logic to the sophisticated CMOS microprocessors and microcontrollers of today), for applications ranging from low-level signals, digital processing and computers, audio/video and communications, imaging, motion control, and mixed-signal.

19. Beginning in 2006 I served as an expert witness in *Twentieth Century Fox Film Corporation et al. v. Cablevision Systems Corporation et al.*,[5] which was pending in the U.S. District Court for the Southern District of New York, where my participation took the form of Expert Reports, depositions, and court testimony.

[5] on behalf of Cablevision.

Beginning in February 2012 I served as an expert witness in *ABC et al. and WNET et al. v. Aereo Inc.*, [6] pending in the U.S. District Court for the Southern District of New York, where my participation took the form of Expert Reports, depositions, and court testimony. These cases involve remote storage digital video and internet streaming of recorded broadcast television, respectively.

[6] on behalf of Aereo.

IV. Television: A Tutorial

Television: Video Plus Audio

20. Television involves the remote delivery of a moving picture, plus sound. It is accurate to think of the *sound* as continuous; however the *picture* is captured, and then delivered, as a succession of still images, at a rate fast enough that the viewer perceives a scene of continuous motion.[7]

21. Television is distinguished further, of course, by the transmission of this movie-like content to the remote viewer. Originally this was carried out exclusively by terrestrial transmission, via radio waves, to the viewer's antenna and television set. Over time other methods of transmission have been added electrical cable,[8] optical fiber, direct satellite transmission via microwaves – along with recording methods such as magnetic videotape (Betamax, VHS, D-VHS), and optical discs (Laserdisc, VideoCD, DVD,[9] HD-DVD, Blu-Ray, and others).

<u>The Audio</u>

22. The *audio* portion of television is perhaps more easily understood, as it differs little from ordinary sound recording techniques. A microphone converts the instantaneous sound pressure variations into an electrical signal; that is, it creates as its output an electrical voltage that at each moment is proportional to the pressure of the sound wave to which it is exposed. Contemporary audio recording and delivery usually employs two or more microphones, creating "stereo" sound (i.e., two channels), or multi-channel sound (e.g., "5.1 channel sound").

23. Traditionally these signals were processed, stored, and delivered by "analog" methods, which means simply that the signals were treated as smoothly varying

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[7] For conventional cinema style movies, the rate is 24 frames/second; television in the U.S. uses a rate of approximately 30 frames/second.

[8] Known technically as *coaxial transmission line*.

[9] "Digital Versatile Disc."

voltages as they passed through the electronic innards of the amplifiers, recorders, modulators, and so on.[10] Contemporary "digital" technology does it differently: almost as soon as possible, the microphone's signal (the varying voltage that represents the sound) is converted to a succession of numbers (it is *digitized*), and everything that follows is some form of arithmetic on this torrent of numbers that comes tumbling out. Only at the final stage – recreating the recorded sound for the listener is the digital representation converted back to an analog voltage, and then, in the loudspeaker, to a reproduction of the original sound pressure wave.

24. Just to give a sense of the quantity of numbers involved, in the standardized recording technology of the compact disc (CD), the instantaneous sound is *sampled* at a rate of 44,100 times per second (in both stereo channels simultaneously), and each such sample pair is converted ("digitized") to a 16-bit binary number.[11] So, the bits are tumbling out at a rate of $2 \times 44{,}100 \times 16$ 1,411,200 bits per second, or approximately 85 million bits per minute.[12]

25. One might ask why any sane person would want to deal with such a quantity of numbers, when the original analog representation of the sound was so much simpler just a pair of voltages that were varying at most 20,000 times per second.[13] The reasons are several, but they boil down to the contemporary ease and economy of digital processing, combined with the higher efficiency and quality of storage and transmission of audio (and video) that has been properly digitized. To get a sense of those advantages, one need only marvel at the gorgeous images transmitted daily

[0]Common analog recording technologies, now nearly obsolete, include the vinyl record (where the audio signal waveform is embossed as small displacements of a fine groove), and the audio cassette tape (where the audio signal waveform is recorded as patterns of magnetization on a thin layer of magnetic oxide coating on a flexible plastic tape).

That is, a number ranging from 32768 to +32767, those bracketing the "full scale" range of the recorded sound.

[2]The *recorded* bitrate is roughly triple this figure, because of coding, error correction redundancy, and the like.

[3]Or 20 kilohertz, the upper limit of human hearing; and that only for one of relative youth, such youth further possessed of sufficient wisdom to avoid deafening rock concerts.

from planetary probes visiting Mars and Jupiter images that are free of "snow" and other artifacts irreparably added to analog transmission by the effects of unavoidable electrical interference — to appreciate the benefits of error-free digital transmission. And, to get a sense of the density of digital storage, we note that a contemporary 5″ optical disc (dual-layer Blu-ray Disc) holds 80 hours of CD-quality audio, or ten times that amount if modestly "compressed," compared with a mere hour's storage of analog audio on the 12″ vinyl LP phonograph records of yesteryear.[14]

THE VIDEO

26. The *video* is by far the more complicated part of television. The challenge is to reproduce a scene with motion, in color, while preserving adequate fidelity and introducing a minimum of artifacts. And, this must be done within the resources of the storage and delivery channels – that is, with finite disc storage and speed, and with finite transmission (via broadcast tower, cable, satellite, or Internet) *bandwidth.*[15]

27. Video systems begin with a camera that has an electronic sensor (analogous to a digital camera), and which converts the two-dimensional color scene on that sensor into a succession of *frames*, each of which represents the image at those successive times (for U.S. TV, the rate is approximately 30 frames per second). In traditional *analog* television, the two-dimensional image is converted into an electrical signal by the following method: Imagine a single frame, that is, a still picture. To keep it simple, imagine further that it is monochrome, that is, "black and white."[16] We begin at the upper left, and move horizontally across the picture, generating an electrical voltage proportional to the brightness at each point as we pass by. When we

[4]And a contemporary 3 terabyte 3″ magnetic hard drive that you can hold in your hand holds yet another factor of 60, or 50,000 hours of excellent quality (128kbps AAC) compressed stereo audio.

[5]*Bandwidth* refers to the range of frequencies that can be carried on the cable or other transmission medium. It is technically accurate to think of this, for example, as the range of stations on the radio dial that could be carried with fidelity by a single electrical cable (or other medium). The term is sometimes used loosely to refer to rate of data transfer.

[6]Or, more accurately, *grayscale*.

reach the righthand border, we jump back to the left edge, continuing with another horizontal path, slightly below the first. See Figure 1. We continue in this way until we reach the bottom right corner, at which time we have scanned the entire frame once, in what is known as a *raster* pattern.[17]

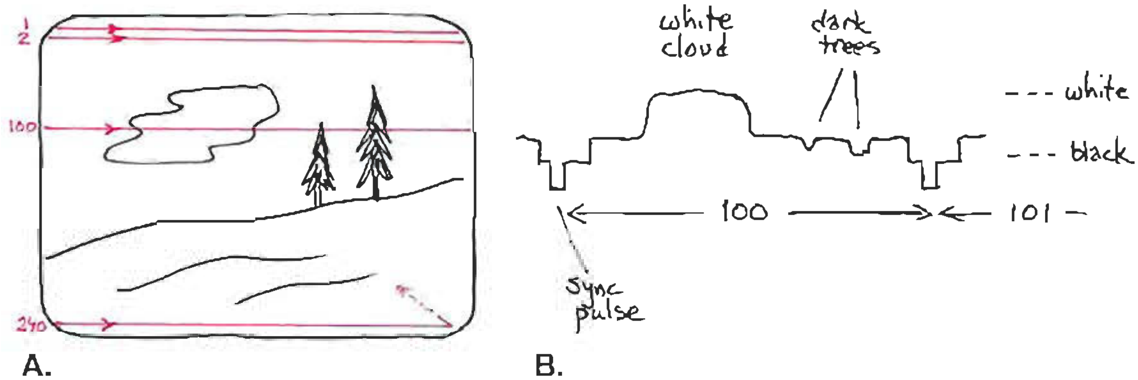

Figure 1: *A static 2-dimensional image (A) is "raster-scanned" to create a video waveform representing intensity along the scan lines. One of the 240 such horizonal scan lines is shown in (B).*

28. What we have done, then, is to generate an electrical representation, in time (a varying voltage proportional to brightness at each point in the image) of a single two-dimensional image; that is, we've converted a two-dimensional image into a one-dimensional output voltage.

29. This time-varying voltage is called the *video* signal, and it is the first step in creating a television image. In traditional NTSC analog television, this signal was transmitted by analog methods, after a process called *modulation* (more below), and was recovered and used by the television set to paint the picture on the screen, performing the same raster scan (left to right, top to bottom). Each frame follows in sequence, presenting a succession of 30 pictures per second on the television set's

[7]Traditional standard definition television (SDTV, usually called "NTSC," for National Television System Committee, and going back to the 1940's) in the United States divides the whole picture into 480 horizontal lines, along each of which roughly 640 features (picture elements, or *pixels*) could be resolved; a computer user would not be terribly impressed he or she would say that standard NTSC television has only "VGA" resolution (i.e., 640×480).

viewing screen.[18]

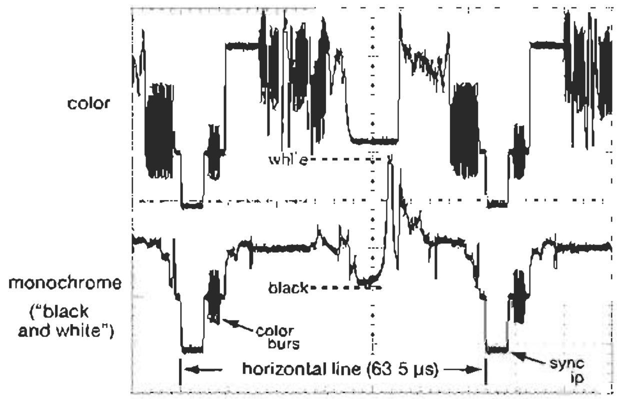

Figure 2: *Composite analog video signal of one horizontal line, framed by horizontal sync pulses. The brightness ("luminance") is represented by its amplitude. Color is accommodated by adding a modulated 3.58 MHz "chrominance" subcarrier, whose amplitude represents degree of saturation and whose phase encodes the colors.*

30. To complete the video signal, it is necessary to add some synchronizing information, so the television set knows when to begin painting a frame, and also when each horizontal line begins. In traditional NTSC television this is done by adding a horizontal *sync pulse* at the beginning of each horizontal line, which is just a short[19] voltage pulse that, if it were in the middle of a picture, would be interpreted as "blacker than black." The television set detects these pulses, and uses them to synchronize its scanning across each line. Likewise, once each field there is transmitted a unique *vertical sync pulse*, which informs the television set when to return to the top to begin painting the next field/frame. The complete video picture signal, with its added sync pulses, is called *composite video*.

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[18] To complicate things, NTSC uses a method known as *interlacing*, in which a coarser raster omitting every other horizontal line is performed at twice the rate. Thus, in standard NTSC U.S. television, the viewer sees 60 pictures ("fields") per second, each of which has only 240 horizontal lines; two such fields, with their interlaced lines, form one complete 480 line frame. This is sometimes called a "480i" format, to distinguish it from formats with higher resolution (e.g., HDTV, with 720 lines or 1080 lines), or from those without interlacing (which are known as *progressive*; e.g., *720p*).

[19] About 4.5 millionths of a second.

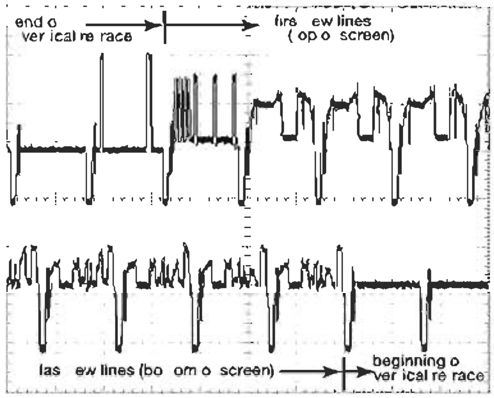

Figure 3: *The vertical retrace (beginning of a new field) is signaled by a set of tailored sync pulses, the first and last of which are shown here.*

Combining and Sending The Audio + Video: Modulation

31. Continuing for the moment with traditional NTSC television (as opposed to *digital* television, whose standards are known as *ATSC*, set by the Advanced Television Systems Committee, and which will be explained later), the composite video, along with the audio, must now be sent, via transmitting tower or cable, to the home viewer. Naively one might think of simply transmitting these signals "as is." This is not done, however, for at least two reasons: First, if the composite video signals were transmitted directly, then any two television signals would overlap and jam each other (because they would all share the same frequency band, namely that of the raw video signal itself); secondly, some wavelengths are more conveniently generated and propagated than others. For these reasons, the audio and video content of television signals (and, indeed, all communications and broadcast signals) are instead used to vary some aspect of a "carrier" wave, chosen at some specified wavelength. That carrier wavelength (or, equivalently, frequency) defines the "channel"; and the process of impressing the information (video/audio) onto the carrier wave is known as *modulation*.

32. Radio stations use the same technique: AM stations vary the strength (amplitude) of the carrier (hence "amplitude modulation"), whereas FM stations vary the frequency ("frequency modulation"). The carrier frequency itself defines the channel: in the U.S., AM stations are assigned to carrier frequencies between 520 and 1710 kilohertz (kHz, thousands of cycles per second), while FM is assigned to the band of carriers from 88 to 108 megahertz (MHz, millions of cycles per second). In the U.S., broadcast television begins at 54 MHz (Channel 2), and ends at 698 MHz (channel 51), with gaps for FM, aeronautical, and other services.[20]

33. When information (video, for example) is modulated upon a carrier, the resultant signal spreads out, and occupies a small band of frequencies. For example, when an FM station varies the frequency of its assigned carrier, to carry its audio signal, the resulting signal occupies about 150 kHz. So, FM stations are assigned channels separated by 200 kHz (to allow a "guard band" of 50 kHz in addition to their 150 kHz signal) and that is why the frequencies of FM stations always end in an odd number after the decimal point (for example WNYC is 93.9 MHz), ensuring a minimum spacing of 0.2 MHz (200 kHz).

34. Traditional analog NTSC broadcast television used a variant of AM for the picture signal (composite video), and, separately, FM for the sound signal.[21] The assigned TV channels are spaced apart by 6 MHz, each station being permitted to occupy nearly that amount, after allowing for a small guard band. Television sets "know" the frequencies allocated for each channel, and tune to the correct frequency when the user chooses the channel number. For example, if (during television's analog era) one tuned to Channel 13 in the New York City area, the television set's electronics selected the station transmitting on 210 MHz (assigned by the FCC as Channel 13),

[20] You can download a gorgeous multicolor wall sized spectrum allocation figure from www.ntia.gov/osmhome/allochrt.pdf.

[2] That is, the picture and sound signals are carried simultaneously on a pair of designated carrier frequencies within the single assigned television channel.

namely WNET. The electronics in the set *demodulates* the received signal, recovering composite video and audio. The video, with its embedded sync signals, is used to paint the picture, frame after frame, while the audio is sent to the loudspeakers.[22]

35. Broadcast television (and radio) takes place on what is often called the "public airwaves." One needs only a television set (or radio) and an antenna to receive these over-the-air (OTA) public transmissions. Although some countries require licensing of receiving devices (radios and television sets), in the U.S. the broadcast services are freely available to anyone within range of a transmitting tower.

36. Depending on the distance and path from the broadcast station to the viewer, the home television antenna has traditionally been as simple as an indoor "bowtie" or pair of "rabbit ears," or as elaborate as a roof-mounted multi-element structure. Whatever its form, the antenna's function is to create an electrical signal on the feedline, induced by the speed-of-light broadcast signal passing by the antenna's site. That signal is connected via a transmission line to the TV tuner, which amplifies, selects, and processes the channel to be viewed.

37. *Cable* television sends traditional analog TV channel signals in almost exactly the same way as broadcast. An evident difference, however, is that the channelized signals are received at the viewer's end from a coaxial cable (rather than being received by the viewer's television antenna), and then connected to the television set directly (i.e., to its normal antenna connector on the rear). Alternatively, for additional cable services (such as premium channels) the incoming cable connects to a "set-top box" provided by the cable company, the output of which is connected to the viewer's television set (or flat screen monitor, projector, etc.).[23] The channel

[22]In this primer we have ignored details associated with reproduction of *color* (*vs* black & white).

[23]For better picture quality, the latter connection is usually made not to the set's antenna input (called "RF," for RadioFrequency, meaning the modulated channels discussed above, in ¶¶31-34), but to special audio/video inputs, with names like *s video*, *component video*, *composite video*, *DVI*, or *HDMI*. The latter pair are *digital* connections, discussed below in connection with digital TV.

frequencies are also somewhat different, with Channels 2–13 chosen the same as for terrestrial broadcast, but with the remaining channels reassigned to eliminate gaps.

38. A third difference is that some of the cable content is delivered as a subscription, for which the viewer pays additional fees; examples are premium services such as HBO. These require some method for permitting or denying viewable delivery of selected channels or programs. Continuing for the moment with analog cable (whose days are numbered!), this can be done in several ways: the simplest is by installing filters (to block unsubscribed channel frequencies) at the utility pole, where the subscriber's cable splits off from the trunk running along the street;[24] A more sophisticated method involves scrambling the cable-borne analog signals of subscription programs,[25] and then instructing the set-top box (via digital communication from the cable provider to the individual STB) as to which programs may be unscrambled.

39. It is worth noting that cable companies have been required to carry the broadcast stations in their area, normally as analog cable channels.[26] Each such program occupies a cable channel (frequency). However, they may distribute additional services via digital methods ("digital cable"), on additional channels (frequencies), which they much prefer: that is because, with digital methods, it is possible to carry up to *ten* NTSC-quality programs (i.e., SDTV, for "Standard-Definition TV") on a single channel. This is called a *multiplex*:[27] the ability to carry multiple *programs* on a single channel (i.e., frequency). And, note that a cable can carry more than 100 such carriers permitting more than 1000 simultaneous programs.

40. Previewing some additional characteristic of digital television: digital cable

[24] Vintage cable subscribers will remember calling the cable company to add a movie channel, whereupon a cable truck appeared, the cable guy went up the pole to fiddle with something (changing the filter), and, voilà, movies on your television!

[25] For example, by suppressing the horizontal sync pulses, or inverting the video (interchanging black and white).

[26] Unless all subscribers are provided with STBs that can receive digital delivery.

[27] Or sometimes *multicast*.

permits flexible subscriptions, with a program being authorized on-the-fly (e.g., pay-per-view, or video-on-demand). It allows for interactive participation, via a reverse channel back to the cable provider. It permits the delivery of high-definition content, with more than the 480 lines of NTSC (up to 1080 lines, at the highest quality currently supported). Finally, it provides a natural way to time-shift, pause, or replay live programs, via computer-type hard disk storage.

41. Analog broadcast was largely sent into retirement in the United States in June of 2009, and all television broadcast delivery is now done by digital methods (more to follow). This conversion-to-digital process is taking place worldwide, and will likely be complete by 2020 or earlier.

Digital Television: What Is It?

42. Just as an *audio* signal can be digitized (i.e., its instantaneous amplitude is measured, at rapid intervals, and converted to a succession of numbers), and subsequently transmitted, stored, or processed (¶¶23 25, above), so it is possible to digitize the *video* signal that represents successive frames of picture. Although one could imagine simply sending the digitized version of traditional NTSC as "digital TV," in practice one takes advantage of the enormous processing finesse of contemporary digital electronics to economize by *compressing* the raw video signal to a small fraction of its native size before it is delivered. The use of compression, along with the fact that a digital signal is "just numbers," permits the delivery of multiple programs on what would otherwise carry just a single video signal (program), typically by a factor of five to ten.

43. There are several reasons for this improvement. One is the ability to detect and correct transmission errors by numerical techniques, allowing one to operate with received signal levels that are close to the "noise" (from interference, or signal loss due to range or obstructions); with purely analog transmission a large received sig-

nal/noise ratio is necessary to reduce the visible effects of noise ("snow") to acceptable levels.

44. A second reason is the spectral efficiency of digital transmission or, more accurately, its improvement compared with the *inefficiency* of analog signaling. This can be seen in Figures 4 and 5, a pair of spectra taken directly off my home antenna in March of 2009, a time during the switchover to digital when both analog and digital broadcasts were taking place.

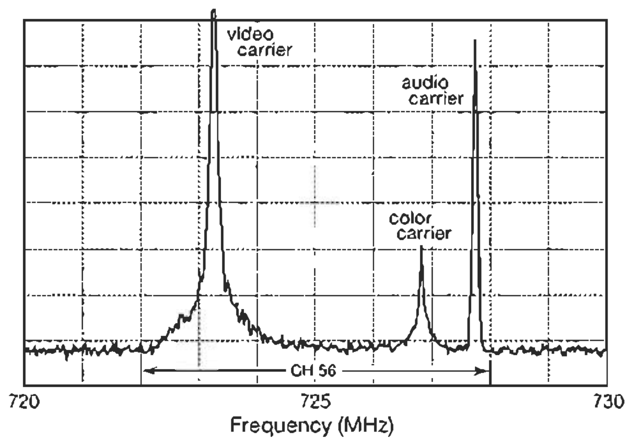

Figure 4: *The spectrum of 6 MHz-wide analog Channel 56 in Boston, as seen in May 2009. The video information resides in the sideband tails, while most of the transmitted power is wasted in the non-informational video carriers.*

45. Compression aims to reduce by a large factor (tenfold or more) the quantity of numbers needed to describe the succession of picture frames, without significantly degrading the image quality. This seemingly impossible task takes advantage of redundancies in a moving picture, and of limitations in human visual perception.

46. Contemporary digital video compression is a rich and mathematically complex subject, the result of enormous effort in the applied mathematics and electrical engineering communities over the last several decades. But the basic tricks are easy enough to understand. The process begins by exploiting the fact that portions of an

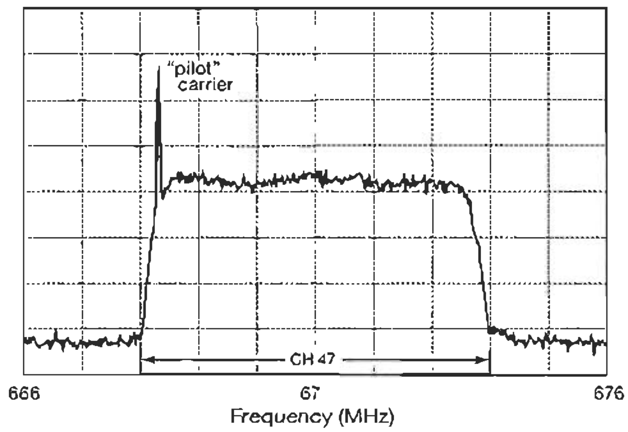

Figure 5: *Digital Channel 47, seen also in May 2009, fills its 6 MHz spectrum allocation with digitized video. It carries five times as many programs, with comparable (or better) picture quality.*

image near each other tend to be similar; so one can encode and send the (smaller) *differences* of brightness/color from a set of reference points, rather than the full description of brightness/color at each point. Likewise, successive frames tend to be similar, so one can define a sparse collection of index frames, and send only the differences for intervening frames.[28] A further trick exploits the fact that the image often contains moving objects, or a panning camera; so it is efficient to calculate "motion vectors" predicting the approximate motions, and then send only the (smaller) corrections from the predicted values.

47. These methods greatly reduce the needed bitrate (number of numbers per second), and they do so *without any loss of picture quality whatsoever* they are "lossless." That is because the original digital image can be fully and exactly recovered by applying the numerical differences in the reverse order. However, further bitrate reduction is desirable (and often necessary), and this is accomplished by *lossy* compression. This consists essentially of discarding the less important image information (from a psychovisual standpoint); the tradeoff is a somewhat degraded

[28]More precisely, it is the corrections from an *interpolated guess* between index frames (or reference points within a frame) that is sent.

image (the degree of degradation depending on the degree of compression), which however can differ from the pristine original in ways that are hardly perceptible to the viewer.[29] The mathematics involves methods with names like Discrete Cosine Transform, Variable Quantization, and Huffman coding; but the bottom line is that these methods permit a large reduction in bitrate with a relatively small reduction in perceived image quality.[30]

48. The tradeoff of image quality with bitrate is gradual, and somewhere in the process a decision is made as to the desired final bitrate.[31] A major constraint is imposed by the fact that both digital broadcast and digital cable television in the U.S. is sent on channels that conform to the same 6 MHz channel spacing that has been used for television since the 1940's. In practice (see ¶54, below) it is possible to send about 20 million bits per second (Mbps) on an over-the-air digital broadcast channel, and nearly double that on a digital cable or satellite channel. A typical compressed bitrate for over-the-air NTSC-quality (SDTV) digital video is about 4 Mbps; thus digital broadcast television stations are able to combine up to 5 or so NTSC-quality programs on a channel. (Recall that a frequency "channel" is no longer a single "program," because of multiplexing. More on this beginning at ¶50, below.) High-definition (HDTV) content requires nearly the full broadcast bitrate, so only one HDTV program can be broadcast on a channel. By contrast, cable or satellite systems, which are not constrained to use the less efficient MPEG-2 compression, are able to

[29] If such effects are noticeable, they are called *compression artifacts*; these are sometimes seen, in over compressed "jpeg" still photographs, as the patchy blocks or the "mosquito noise" around edges. Similar considerations apply to lossy audio compression, for example highly compressed "MP3" music files.

[30] The video compression recipe used for all digital TV broadcasting in the U.S. is named "MPEG 2," and described in the Advanced Television Systems Committee documents A/53 and A/54 (see www.atsc.org). An improved set of compression methods are incorporated in the set of standards known as MPEG 4; these are widely used by the cable and direct broadcast satellite services, as well as for video streaming over the Internet.

[3] Which is permitted to vary, as program content changes. This is known as *variable bitrate*, or VBR, as distinguished from *constant bitrate*, or CBR.

combine as many as eight HDTV programs onto one channel when using efficient H.264/MPEG-4 encoding.

49. It is worth admiring the impressive bitrate reductions that these methods are achieving: a simple calculation[32] shows that digitizing an HDTV program without any compression would produce a bitrate of roughly 1000 Mbps, whereas contemporary compression methods reduce this to a modest (and deliverable) 20 Mbps, a 50-fold reduction! And comparable reductions are routinely achieved with SDTV.

Digital Television: Broadcast, Cable, and Satellite Delivery

50. Over-the-air digital television broadcast and digital cable television both use traditional frequency "channels," upon which they put a stream of numbers (the compressed video described in ¶¶42 49, plus the associated digitized audio), instead of the continuous analog waveform that was used in traditional NTSC television. Because of the economical bitrates produced by compression, there is adequate capacity on a single cable (or broadcast) channel frequency to multiplex several simultaneous programs. One can think of these as sub-channels.[33]

51. Satellites provide an alternative to over-the-air or cable/fiber delivery of television programming, and satellite delivery is particularly welcome in areas not served by wired broadband connections. This is known variously as Direct-To-Home (DTH), Direct Broadcast Satellite (DBS), or Broadcast Satellite Services (BSS), and exploits (usually) satellites in geostationary orbit, i.e., in the equatorial "Clarke" orbit of radius 42,200 km, where a satellite's period matches Earth's rotational pe-

[32] Bitrate is approximately 1080 lines × 1920 pixels/line × 30 frames/second × 16 bits/pixel, which multiplies out to 995,328,000 bits/second.

[33] Because the cable (or broadcast channel) has a fixed total bitrate, the bitrates of the individual programs that are being multiplexed must be adjusted such that their total combined bitrate matches the channel capacity. This is called *bitrate grooming*, and involves *null padding* (adding nulls, to increase a program's bitrate), on-the-fly compression (to reduce a program's bitrate), or even time shifting of program content (to prevent unlucky alignment of peak bitrates of the various programs). Digital television packets include "presentation time stamps," so it's OK to move things around a bit as they flow through the various digital pipes on their way to the television screen.

riod of 23h56m4s.[34] As surprising as it may seem, a single satellite with a 200 watt transmitter can deliver a half-dozen high definition programs (or 30 "standard definition" programs) simultaneously to small dish antennas on houses everywhere in the continental US. Typical DBS satellites are equipped with a dozen or more such "transponders," and the receiving dish antennas use multiple "feeds" (two to four, for DISH Network) to point at several satellites, making available many hundreds of television programs.

52. Early DBS systems used a 4 GHz (C-band) downlink, and required large dishes (> 3m diameter) and expensive RF electronics. Contemporary systems operate around 12 GHz (Ku-band), with mass-produced oval receiving dishes (typically $20'' \times 24''$) that incorporate several low-noise RF amplifiers, each with local oscillator, downconverting mixer, and IF amplifier in an integrated LNBF (low-noise block-downconverter plus feed) unit that sits at the focus of an off-axis (to reduce scattered ground noise) parabolic dish. That's an impressive amount of hardware for a cost of roughly $100. The dish connects to a set-top box (often with DVR), similar to what's used for cable TV, but which is designed to select from the dish's several feeds and polarizations, and to receive the intermediate frequency (IF) band coming down from the dish on standard video coaxial cable. As with cable TV, the content providers control available programming, via subscription-enabled decryption. Satellite systems are not bound by over-the-air terrestrial standards (e.g., MPEG-2 encoding), and they generally use more efficient schemes such as MPEG-4. They also use a wider channel bandwidth (27 MHz versus 6 MHz), and a different modulation (e.g., QPSK or 8PSK), producing a delivered transport stream bitrate of approximately 40 Mbps. A single such channel can carry eight high-definition television programs

[34] A surprise to many, who thought it was 24 hours. Not so — we're in orbit around the sun, which adds an extra 4 minutes (1/365th part of a day) to Earth's true rotational period (the *sidereal* day) to arrive at the 24 hour *solar* day (the average time from solar noon to solar noon).

simultaneously.

53. For either OTA digital broadcast or digital cable or satellite, the set-top box (STB) or equivalent hardware within the television set receives the multiple channel frequencies, each with its multiplex of programs. The STB or television knows the program assignments within each channel, and is able to pull out the sub-channel that the viewer selects, which it identifies by assigning a "virtual channel number." That is what the viewer chooses it is displayed on the STB, and on the screen during selection. For example, the viewer might select HBO, which is assigned a virtual channel (for example 301), and which might actually be just one of eight sub-channel programs carried on one digital satellite channel frequency. The STB then captures the HBO stream, decrypts and decodes its MPEG encoding, and converts it to displayable video for a television monitor (or flat screen, etc.).

54. In more detail, and in the language of digital television engineering, the delivery channel (digital broadcast or digital cable) is called the "transport stream," which can be thought of as a data pipe carrying some 20 Mbps (broadcast), or 40 Mbps (cable or satellite) in each frequency channel.[35] The MPEG-2 specification dictates that the data put onto the transport stream must be broken into little *packets* of data, each of length 188 bytes, and each belonging to an individual program. When multiple programs are sent on one transport stream, it is called a "multi-program transport stream," or MPTS; if a single program, it's a "single-program transport stream" (SPTS). Repeating what was said earlier: a broadcaster can put five standard-definition programs (or one HD program and one standard-definition) onto a single broadcast channel's MPTS. The individual packets are identified by program, and they are interleaved in time (see Figure 6).

[35]The disparity between broadcast and cable, each operating within 6 MHz channels, has to do with the particular modulation schemes used: for broadcast it is called "8 VSB," whereas cable uses the more efficient "256-QAM" (pronounced "kwahm"), thereby exploiting cable's better signal carrying properties to carry roughly twice the information content.

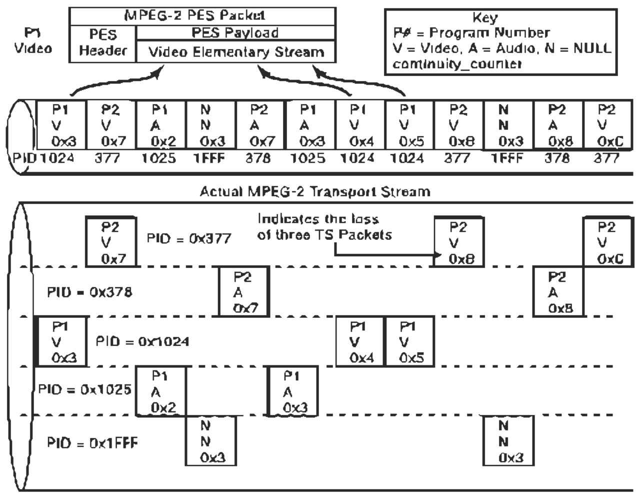

Figure 6: *Multiple programs can be interleaved into one digital transport stream, as a "multitransport program stream." Their individual video and audio packets are tagged with program identifiers (PIDs), by which they can be selected and reassembled. (from Figure 7.1 of ATSC Doc. A/54A.)*

55. To put it another way, the several programs that will be put into a multi-transport program stream (a "program multiplex") are cut into short pieces (packets, about 40 microseconds in length for digital cable), tagged with unique identifiers (called *PID*s, for "program identifiers"), and then interleaved with the pieces (packets) from the other programs that share the same transport stream. At the STB or television set the packets belonging to the selected program are identified ("filtered") by looking for their PIDs, and then reassembled into a single program transport stream to be decoded and displayed.[36] In Figure 6 there are two programs (P1 and P2), each with video (V) and audio (A), with their corresponding PIDs (1024, 1025, 377, 378); they are shown as the interleaved multiprogram stream at the top, and as filtered into their respective single-program streams at bottom.

[36] "Presentation Time Stamps" (PTSs) accompany the packets containing the audio, video, and subtitles, providing the information needed so that they can be displayed with correct timing and synchronization.

Premium Services and Conditional Access

56. Satellite and cable television providers offer premium services, such as Showtime, HBO, and pay-per-view, for which the subscriber generally pays additional monthly fees. A customer whose subscription includes Showtime, for example, is able to view (and record, if the STB includes a DVR) programming delivered on the several Showtime channels. Although each customer has their own dish antenna (or incoming cable), the same signals are received by many subscribers, so the provider needs a method to control each subscriber's access to the full channel lineup.

57. To limit access within the full suite of distributed programming, the provider includes *conditional access* information along with the video and audio. This is done by including "CA" packets, along with the usual V (video) and A (audio) packets that comprise one program within the multi-program transport stream. The STB includes decryption hardware, and uses the CA packets to provide the key information to unlock the encryption that is imposed on the video and audio packets by the satellite or cable company.

Home Television Recording

58. Video recording was complex and costly (and therefore confined to the broadcast studios) until 1975, when home video recording devices were introduced in the U.S. by Sony ("Betamax") and its competitors ("VHS," for video home system). These devices replicated the "front-end" of a television set, to recover video and audio from the incoming signal (broadcast or cable), and used a clever spinning tape head arrangement[37] to capture on magnetic tape a reasonable replica of an NTSC analog television program. The technique was entirely analog (no digitization, no numbers), and recorded only onto special video tape media (no computer media, no "hard disks,"

[37]This is known as a "helical" tape head, which creates successive narrow slanted tracks across the slowly moving tape, each one holding one field of video. The use of a rapidly moving tape *head* eliminates the need for rapidly moving *tape*.

etc.), as a magnetic recording (analogous to an analog audio tape recording; see the footnote at ¶23). Videotapes for home recording were packaged in cassettes, thus *video cassette recorder* (VCR).

59. Video cassettes retained their recording for timescales of years, and could be replayed numerous times; with their cardboard sleeves and adhesive labels, they could be organized into library-like collections. During viewing they could be paused, rewound, or fast-forwarded; and they could be re-recorded with new content. Only one program could be recorded at any time, although most VCRs allowed viewing of a different channel during recording.

60. Videotape technology has been upstaged by digital alternatives such as optical disc recording (most famously in the form of DVD's and Blu-ray discs whether sold with pre-recorded content, or recorded with a disk recorder), which creates a permanent copy of the video material; or by recording to a computer-type hard-disk drive ("hdd"), where the video copy is stored as a computer file. These digital methods require that the program material be converted from analog to digital form, if it is not already.

61. The conversion of the analog audio and video of the real world into digital form requires some fast and complex electronics but it makes the task of *recording* straightforward. Early digital video recorders (DVR) such as the TiVo®, introduced in 1999, performed this conversion (from the analog television broadcast) internally, and allowed recording directly to hard disk; others, such as the Panasonic DMR-E80H, included both a hard drive (like TiVo) and a DVD recorder, so that recorded programs could be viewed conveniently from the hard drive, and also recorded onto a DVD for archiving.

62. With the advent of *digital* television (as broadcasts, cable, or satellite), the recording process became simpler, and better. That is because a single program

received at the STB or OTA television receiver is, in essence, just a stream of numbers, which can be filtered from the multiprogram stream, assembled in a temporary memory "buffer," and written to a hard disk file just like any computer file.[38] In that sense, a set-top box or OTA receiver with digital video recorder (DVR) is simply a special-purpose computer, with the usual processor, hard drive, etc., and having additional hardware to do the special digital video tasks receive the broadcast or cable signal, generate the displayable output, take control commands from the infrared remote "clicker," and so on. (This similarity is illustrated in the photographs attached to this declaration, showing the interior of an IBM desktop computer and of DVR-STBs from DISH Network and from DirecTV.) A typical contemporary set-top box or OTA receiver with DVR contains a computer processor chip and associated memory, a hard drive of 250 GB or greater capacity, and various video-related additional hardware (input tuner, video memory, display and audio drivers, etc.).

63. As with the early Betamax and VHS recorders, contemporary DVRs provide functions such as pause, rewind, and fast-forward. But their brainpower lets them add playback capabilities such as discrete jumps forward (often in 30-second increments) and jump backward, scheduled recording of multiple episodes of a program. and even program suggestions based upon past preferences. Contemporary DVRs include multiple tuners, for simultaneous recording of several programs; top-of-the-line units such as the DirecTV Genie include five tuners and 1000 gigabyte or larger hard disks, capable of storing hundreds of hours of high-definition television.

64. It is worth noting that any digital storage medium of adequate speed and capacity can be used to store digital video content; at the consumer level there are many "personal video recorders" (PVR) that store programs on recordable DVDs or onto solid-state "flash" memory chips. There are also digital video tape recorders

[38] And, like a computer file, the recording can be done without degradation of the information.

that can store both SDTV and HDTV onto a digital variant of VHS tape. And a commodity personal computer (PC) can store downloaded video content on its hard drive.

Video-on-Demand

65. Cable and satellite providers also make certain types of programming available to customers on an individual basis. Some of these (e.g., movies) consist of content that may never have been transmitted in normal "linear" fashion; or they may include television programs that were previously transmitted and have been stored by the provider for later viewing by individual subscribers, at their request. Both of these are to be distinguished from linear programming content that is sent to (and viewable by) subscribers at the scheduled time whether the subscriber viewed such content live, or recorded the programs during linear transmission for viewing at a later time (time-shifting).

66. How is it possible to provide program material specifically for an individual subscriber, for example "on-demand" delivery of a previously aired television program, or of a movie, on a cable network that serves an entire city, or a satellite system that serves the whole country?

67. In the case of cable television, such services are made possible by the fact that the cable provider is able to tailor the particular group of signals carried on its cables that go to different groups of cable subscribers in an area, combined with an ample reserve of unused channels (in addition to the standard lineup). So the cable provider can deliver individual content to many thousands of subscribers simultaneously. On-demand viewing requires also a reverse channel for each subscriber, so that they can communicate back to the cable company to select programming stored on remote servers, and also pause (or fast-forward or rewind) the material.

68. The same *delivery architecture* transmission of video content to an indi-

vidual subscriber via a dedicated sub-channel, with a reverse channel for subscriber control was used in Cablevision's remote-storage DVR. But the similarity ends there: In the case of VOD, the content has been chosen by the cable provider (with terms negotiated with the content provider) and stored in advance (with trick-mode copies[39] in designated servers to stream to any of multiple requesting subscribers. In the case of RS-DVR, by contrast, the recording was made at the direction of the subscriber, at the time of normal linear delivery (and in a channel included in the customer's subscription), in a unique copy playable only by that subscriber.

69. For satellite providers the VOD task is complicated by their wide coverage (at least a few thousand square miles, for each of the satellite's regional "spot beams," and some 3 million square miles for the country-wide "CONUS" coverage). It's simply not possible to provide individual program streams to millions of subscribers.

70. To provide VOD services, then, the satellite providers can pre-deliver a suite of popular VOD titles (movies, for example) to the DVRs of subscribers, as encrypted content with conditional access. These are separate from the linear programming channels that are delivered in real time. A subscriber can view one of these VOD programs, pausing and rewinding at will, without requiring any communication from the satellite.[40]

71. An alternative mode of VOD delivery is available to subscribers with a broadband internet connection: the program content can be streamed to the viewer from remote servers, in the same manner as streaming services such as Netflix® or HBO GO®.

[39] "Trick mode" (or "trick play") refers to the way in which fast forward or rewind is created and displayed in digital television systems. Because of the complexity of digital video decoding, this is most often accomplished by storing one or more separate fast play video copies at the remote server, to be delivered during times when the viewer requests fast forward.

[40] For billable content the STB communicates back to the provider via an internet or telephone connection.

V. DISH Network's Satellite System

72. The remaining sections deal with specifics of the DISH/EchoStar satellite television system. For simplicity I will use the term "DISH" to refer to both DISH Network and to its technology provider EchoStar.

Content: Regional, CONUS, and VOD

73. Television broadcasts are not the same in different geographical areas of the country. Nielsen maintains[41] a set of 210 regional Designated Market Areas (DMAs), within which viewers receive similar television programming.[42] Any location in the continental US (CONUS) belongs to a DMA; a mathematician would say that the DMAs provide a *tiling* of CONUS. The major networks' programs are carried by local stations, and such programming when delivered by direct-broadcast satellite providers must adhere to the geographical location of the subscriber.[43]

74. For this purpose DISH maintains local receive facilities (LRFs) that collect and aggregate signals from television stations in each of the DMAs; these signals are received variously by local antennas receiving the corresponding off-the-air transmissions, or by direct optical fiber link from the broadcast station. The signals are transcoded from their native MPEG-2 into the more efficient MPEG-4, then encapsulated into IP packets and sent via wideband dedicated fiber links to one of DISH's uplink facilities.[44] As described below in ¶78, DISH's satellites use relatively narrow "spot" beams to deliver regional television content.

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[41] As stated on their website at http://nielsen.com/us/en/campaigns/dma maps.html, "DMA (Designated Market Area) regions are the geographic areas in the United States in which local television viewing is measured by The Nielsen Company."

[42] See for example the listing of "Coverage Maps for All Designated Market Areas" at http://transition.fcc.gov/dtv/markets/, http://transition.fcc.gov/mb/shva/, or Nielsen's site at http://nielsen.com/us/en/measurement/television measurement.html, http://www.nielsen.com/us/en/campaigns/dma maps.html, and listings at http://nielsen.com/content/dam/corporate/us/en/public factsheets/tv/2012 2013 DMA Ranks.pdf.

[43] See Code of Federal Regulations, Title 47, §76.66 "Satellite broadcast signal carriage."

[44] The primary uplinks are in Cheyenne, WY, and Gilbert, AZ; there are in addition four regional uplinks, and four unmanned "micro regional" uplinks.

75. Much of DISH's programming is national, thus not restricted to the regional DMAs; examples include public channels such as NASA or CSPAN, commercial networks such as CNN, and premium channels such as HBO. DISH calls these "CONUS" stations, and they are delivered to any DISH customers within whose subscription package they are included.

76. Finally, there is the category of Video-on-Demand (¶¶65 71). Unlike cable providers, where VOD content is streamed in real time from remote servers to individual requesting subscribers, DISH (in common with other satellite systems, see ¶69) uses two methods of VOD delivery: (a) some popular pay-per-view movie content is "pushed" down to the DVR, playable (and rewindable, etc.) directly from the hard drive; and (b) a larger body of additional content (e.g., previously aired programs from Bravo) is available as streaming video to those STBs with an internet connection. Television content that was delivered during normal (linear) broadcast and that was recorded on the subscriber's video recorder is not "video-on-demand."

Uplink and Satellites

77. The primary and regional uplink facilities receive their multiplex of programs via IP connection, from which they assemble and uplink the MPEG-4 multiprogram transport streams to the various satellites in the DISH constellation. The uplink transmit dishes are large ($\sim$ 30 ft in diameter), both to ensure a reliable link at low elevations and in all weather, and to provide a very narrow beam that targets only the intended satellite.[45]

78. The several DISH satellites serving the U.S. are located in geostationary orbits, spread across longitudes from 61.5°W to 129°W. They have directional uplink antennas (to separate signals from the different uplink stations), and a mix of

[45]There's *physics* going on here: the angular width θ of the transmitted beam gets smaller as the dish diameter D gets larger, and is given approximately by $\theta = 60D/\lambda$ degrees, where λ is the wavelength of the transmitted radio signal. For DISH's uplinks that works out to be a directional beamwidth of about 0.1°.

directional ("spot") and CONUS-coverage downlink transmitting antennas, for DMA and CONUS programming respectively. The satellites perform no processing of the television signals, they simply retransmit them downward at a different frequency; this is sometimes called a "bent pipe." Both links operate at wavelengths of roughly 1 inch (known as "Ku-band").

79. At the satellite a set of *transponders* perform the bent-pipe function, converting the received uplink data stream into a transmitted downlink stream at a somewhat different wavelength. [redacted]

80. The transmitted downlink signals take advantage of what's called *polarization*, so that two completely separate signals can be carried [redacted]

Residential Dish Antenna

81. The familiar south-facing residential dishes that are seen decorating homes are, of course, the receiving antennas that capture the delicate transmissions after their 50,000-mile journey. They are much more than mere "antennas" perhaps more properly admired as the marvel of sophisticated engineering that they represent. One such dish represents about a hundredth of a millionth of a millionth of the U.S. land area, so it receives from a typical CONUS transponder roughly a millionth of a

millionth of a watt, from which it must extract a half dozen error-free high-definition television signals.

82. The dish reflector is a precisely formed parabolic section, the unique shape that brings parallel rays to a point focus.[46] At the focus (or foci, for a dish that captures the signals from more than one satellite) is an elegantly engineered device called a "low-noise block downconverter and feed" (LNBF). It does the following: (a) it funnels the incoming wave, separating the two polarizations, and converting each to a corresponding electrical voltage on a wire (thus the *feed*); (b) it amplifies these very feeble signals, oscillating at some twelve billion times per second, while effectively minimizing the addition of electrical noise (thus *low-noise*); (c) finally it converts the signals to a lower "intermediate frequency" (IF) band, a process called *downconversion*, with the received polarizations separated into different IF band segments.

83. It is these signals that come down the cable, the result of substantial electronic processing up at the dish. The electronics at the dish includes amplifiers, oscillators (tiny transmitters used for downconversion), mixers, filters, and other support electronics, powered by an electrical signal that is sent up the same cable by the Hopper.[47]

84. One may be puzzled by the peculiar orientation of home dish antennas why are they sometimes pointed so low that they seem to be aimed at or below the horizon? There are two parts to the answer: first, the constellation of geostationary satellites spans an arc across the southern sky, populated worldwide with some two hundred satellites; over the longitudes of the U.S. alone there are some 35 satellites parked in geostationary orbit.[48] The line of satellites across the southern sky dips

[46] A fact known in Greek civilization since at least the 4th century.

[47] Because the Hopper has three tuners, an additional step of frequency conversion is required to bundle three IF bands onto one cable; this is done in a separate device called a "solo node."

[48] Hardly "parked," of course they are in equatorial orbits, whizzing around the earth at nearly 7,000 miles per hour, to keep up with Earth's rotation.

down to the horizon at its eastern and western ends.[49] Second (and technologically more interesting), the geometrical arrangement of the receiving dish is what's called an "offset-feed paraboloid." That is, the little conical feeds are offset below so they do not block the incoming signal. This makes the dish appear to be pointing some 25° lower than it is, thus the explanation for the apparently "subterranean" satellites. This peculiar arrangement is used to eliminate blockage of incoming signal by the feedhorns, and also to reduce the encroachment of thermal radio noise that is emitted by the surrounding environment another bit of thoughtful design that enables successful direct satellite broadcasting.

[49]You can get a good sense of the satellite arc with a mobile app called DishPointer: when you point your smartphone into the sky it shows the satellites as bright red circles (with their locations) on a red arc, superimposed on the camera view (with obstructing trees, etc.) seen by the mobile device.

VI. DISH Network's "Hopper" Set-Top DVR

Hopper: The Inside View

85. DISH Network announced its most recent STB-DVR, the "Hopper," in January, 2012, at the Consumer Electronics Show in Las Vegas. The relevant improvements upon earlier DISH STBs include the ability to serve up to three connected "Joey" mini-STBs, three independent tuners, and a larger (2 terabyte) hard drive.

86. In somewhat greater detail, the Hopper's hardware includes a dual-core microprocessor that runs Linux, and executes firmware [redacted] In common with computer hardware generally (see the photographs in Exhibits A C, showing the inside view of a Hopper, a DirecTV STB, and an IBM desktop computer), it has an Ethernet network interface, several USB ports, and digital audio and video outputs. Befitting its satellite STB purpose, it adds a coax input for connection to the receiving dish (with corresponding communication hardware inside), and additional television outputs (analog component and composite video, and digital HDMI); and it comes with a familiar remote control "clicker" that communicates with the Hopper or Joey on a radio channel (unlike most remote controls, which use line-of-sight infrared).

87. The Hopper receives satellite signals via a rear-panel coax connection, which serves both as the power source for the dish antenna's electronics, and the input port for receiving the outdoor dish antenna's downconverted signals (see ¶¶81 84). The Hopper's hardware performs an additional step of tuning, followed by demodulation, demultiplexing, and descrambling (decryption) to recover the selected program's video and audio content. That content is available for display on a television monitor, for recording, or for viewing by a connected Joey mini-STB. These processes are under the control of the microprocessor and associated computer electronics, running computer code (firmware) held in memory within the Hopper.

88. The Hopper's firmware is tailored to exploit this hardware: (a) It allows a viewer to move between different rooms, with the program material presented seamlessly by the respective Joeys (thus the *Hopper* name); (b) it allows the user to program one of the tuners to record the prime time programming of one or more of the four major networks, retaining the recorded material for as long as eight days[50] ("PrimeTime Anytime," PTAT); and (c) it allows the viewer to enable an automatic ad-skipping feature known as "AutoHop" on most PTAT recordings.

PrimeTime Anytime (PTAT)

89. The PTAT function is, in essence, a streamlined interface to what is conventionally called "timer" recording. The latter dates back to the earliest VCRs (Betamax, VHS) in which broadcasts during a future time slot could be scheduled for automatic recording by specifying starting and ending times during which a chosen television channel is to be recorded. With the availability of electronic program guides (EPG), timer recording has evolved to include the contemporary interface by which a subscriber can designate future recordings by series title ("Series Manager," or "Season Pass"), with smart options such as the recording of new episodes only (i.e., excluding reruns), and the like. Services such as TiVo went a step further, evidencing a whif of artificial intelligence by recommending (and by default recording) programming that a viewer might like (based upon past preferences).

90. The Hopper's PTAT permits the subscriber to designate daily recording of a chosen selection of the four major networks (ABC, CBS, Fox, NBC) during prime time, such recordings to be retained for a designated period selectable from two to eight days. The same outcome would result from a manual timer setup process, for example, if an owner of a TiVo Premiere 4 programmed one or more of its four tuners to record corresponding network programming during the same prime times. The

[50]The subscriber can elect to save any PTAT recording for a longer term, if desired.

Hopper has only three tuners, but DISH has grouped the four network HD channels onto a single satellite transponder, thus enabling the PTAT software to record them all with a single tuner.

91. Once PTAT has been enabled by the user, with selection of networks, choice of days to record, and duration of retention, the recording process is automated by the Hopper software. Predefined rules determine what hours are included in "primetime," currently 8PM 11PM Eastern time weekdays and Saturday, and 7PM 11PM Sunday. Software rules also determine whether a program that straddles either boundary is included – at least half of it must fall within the defined primetime window. The PTAT recording process takes place on schedule and without interruption, unless it has been disabled by the subscriber at least 15 minutes earlier; this lockout provision was implemented by design, to prevent unintended disruption of the full suite of nightly PTAT recordings.

92. PTAT is recorded at the subscriber's home, at airtime, from the linear satellite television signal that is being received normally. The recording is made on the Hopper's hard disk in a unique copy for the subscriber's later use only. It shares these attributes with any home DVR that the subscriber would program for timer recording of designated programs or channels at designated times; for example, if a network program is interrupted for local "breaking news," that is what will be recorded in either scenario.

AutoHop

93. The Hopper's *AutoHop* function, when directed by the viewer, skips over the commercial segments between program segments when playing back a PTAT recording. It is available beginning on the day following recording, and it can be invoked by the viewer at the time a PTAT recording is selected for playback.[51] When

[5] It may be unavailable for some programs, for example sporting events or local news.

AutoHop has been thus enabled, the program segments play normally, but only the first and last few seconds of each block of commercial breaks are visible to the viewer. Rewinding or fast-forwarding into a commercial segment disables AutoHop for that segment. AutoHop is not available when PTAT content is viewed remotely via the Sling Adapter.

94. In essence, AutoHop lets the Hopper automate and improve the 30-second skip function available on most DVRs, by [redacted] During AutoHop playback the Hopper skips over the commercial segment (displaying instead the marsupial hopper icon). The recorded video, both program and commercial segments, is not modified.

95. [redacted]

[redacted]

[redacted]

96 [redacted]

97. [redacted]

[redacted]

98. An earlier protocol used by DISH involved a quality assurance step in which [redacted] was tested against a PTAT recording made by DISH, to ensure its accuracy. I have been informed that this procedure is no longer in use; no network programs are recorded by DISH in any step of the AutoHop process.

VII. Comparison with Capabilities of Other DVRs

99. As noted in ¶90, the ability to set simultaneous automatic timer recording of all primetime HD broadcasts from the four major networks is present on contemporary DVRs with four tuners, such as the TiVo Premiere. The Hopper's PTAT accomplishes the same result, but with a streamlined user interface that includes options for customization (selection of networks, days of week, and number of days to save the recordings).

100. Likewise, as noted in ¶94, the ability to skip forward in 30-second jumps (and sometimes other intervals) during playback of any recorded content is common in contemporary DVRs (e.g., my Comcast-supplied Motorola STB-DVR). In addition, most DVRs provide several speeds of fast-forward (and rewind), which let the viewer navigate quickly to the next program segment.[54] Most DVRs also provide an "instant replay" button on the remote control (my HR10-250 jumps back 8 seconds, while my Comcast has a 15-second option), useful when overshooting the beginning of a segment while high-speed fast-forwarding. Put another way, viewers of home-recorded television have always had the ability to skip forward over any portion of a recording, beginning with the mechanical buttons of early Betamax and VHS machines. Successive generations of consumer video recorders (particularly digital recorders with hard disk storage) have made the process easier. The AutoHop, if activated by the viewer, accomplishes a similar result.

101. These skip-forward capabilities were present in many of the earlier analog VCRs as well. For example, my JVC HR-S9900U offers a "Skip Search" that causes automatic fast-forwarding in increments of 30 seconds (up to 2 minutes). Similar functionality is found in JVC's HR-XVC19S combined DVD/VCR, where it is called "Commercial Skip," as well as in competing VCRs from other manufacturers (e.g.,

[54] During fast forward operation the video is displayed in what might be called "fast motion," while the audio is generally muted.

the Panasonic PV-V4524S, Sony SLVN500, or Toshiba W-522).

102. Several analog VCRs went further, offering a feature that automatically fast-forwarded over commercial segments. For example, the Panasonic PV-V4623S manual describes the operation of its "*COMMERCIAL*►►***ADVANCE***®" as "VCR will automatically advance through marked commercial blocks recorded on the tape and then resume playback" (and the remote control includes a CA/ZERO button for this purpose). This same-named feature was found on VCRs from other manufacturers, for example the Proscan PSVR83 and the GE VG4268; the manual for the latter includes this description:

> "COMMERCIAL►►ADVANCE is a patented technology that detects and marks most commercials on your tape for any recording that is more than 15 minutes long. After recording, the VCR rewinds the tape to the beginning of the recording and determines where the commercials are located. It then marks the beginning and end of the detected commercial segments, and when finished returns the tape to the end of the recording. **It does not erase the commercials from the tape.**
>
> During playback, the VCR automatically skips the detected commercial segments, or you can choose to manually skip them. This feature reduces three minutes of commercials to approximately 8 12 seconds of fast forwarding in the SLP speed. You can select a background display of blue or see the video as the commercials are skipped."

103. The manual for the PV-V4623S helpfully includes a footnote informing the reader that *COMMERCIAL*►►***ADVANCE***® is a Jerry Iggulden invention licensed in association with Arthur D. Little Enterprises, Inc., and listing U.S.Pat. Nos. 5,333,091, 5,692,093, and 5,696,866. Interestingly, the '091 and '093 patents describe a process in which the events qualifying as non-program segment markers are stored in a separate "playback map memory" that is accessed during playback; that is, the segment markers are not written onto the tape itself, but held in separate memory storage, closely analogous to the Hopper's announcement and bookmark files.

104. In common with DVRs generally, the Hopper/Joey records only programming that the subscriber has instructed it to (with the PTAT set of programs and

times merely a user-customizable "bundle"). This contrasts with devices like TiVo, which by default will "auto-record" programs that its software algorithms predict may be liked by the subscriber, based upon past preferences.

105. In terms of storage capacity and capability of recording simultaneous programs, the Hopper (with 2000 GB hdd and three tuners, the latter capable of recording 6 programs during PTAT, 3 programs otherwise, plus one additional if equipped with the OTA adapter) is representative of high-end DVRs such as the AT&T U-verse (4 tuners, $\geq$250 GB disk), the DirecTV HMC/Genie (5 tuners, 1000 GB disk), and the TiVo Premiere 4XL (4 tuners, 2000 GB disk). All of these run circles about the original Betamax (1 tuner, 1 tape, no disk).

Supplementation

This declaration represents my current opinions, based upon the materials I have reviewed. If additional materials or information come to my attention, I reserve the right to revise or supplement the opinions in this declaration.

I declare under penalty of perjury under the laws of the United States that the foregoing is true and correct.

Executed this 21st day of December, 2012, at Cambridge, Massachusetts.

Paul Horowitz

Paul Horowitz

Curriculum Vitae — Paul Horowitz

Born: December 28, 1942

Degrees: **A.B.** (Physics) 1965, Harvard (summa cum laude)
A.M. (Physics) 1967, Harvard
Ph.D. (Physics) 1970, Harvard (*Optical Studies of Pulsars*, advisor: R.V.Pound)

Positions, fellowships & awards:

currently Research Professor of Physics and of Electrical Engineering, Harvard University

1965–66	Sheldon Traveling Fellowship
1966–67	NSF predoctoral fellow
1967–70	Society of Fellows, Harvard
1971–73	Alfred P. Sloan fellow
1974–	Professor of Physics, Harvard
1977	Visiting scientist, University of Colorado
1978	Visiting scientist, Arecibo Observatory
1981–82	Senior research associate, NASA Ames Research Center
1982–85	Board of editors, *Review of Scientific Instruments*
1983–	JASON study group
1985	The Year's 100 Top Innovations, *Science Digest*
2003	"Treasured Textbooks," *IEEE Spectrum* (three texts on circuit design were so honored, of which ours is the only one in English)

Electronic engineering interests:

Half-century of circuit design experience — thousands of circuits, hundreds of instruments

Author (with W. Hill) of *The Art of Electronics* (Cambridge University Press, 1980, 1989), a textbook of circuit design, going into its third edition, with worldwide sales of a million copies, and translations into ten languages

Teacher (and originator) of "Laboratory Electronics" design course at Harvard University, taught also at other universities and technical schools

Originator and co-supervisor of the Electronic Instrument Design Laboratory at Harvard

Other research interests:

optical timing experiments on the Crab Nebula pulsar
searches for new pulsars with Fourier and correlation techniques
development of synchrotron radiation facility at CEA
development of a scanning x-ray microscope
development of a scanning proton microprobe in air
studies of the e.coli rotary engine
coded-aperture spectroscope for cometary astronomy
speckle imaging
radiofrequency searches for extraterrestrial intelligence (SETI)
billion-channel digital spectrum analyzer for SETI
astronomical interferometry
search for ultraheavy matter
technologies for humanitarian demining
search for hydrogen condensations in the early universe
optical SETI

Litigation-related and other consulting:

Technical Consulting, on behalf of the US government:

MITRE Corp. (an FFRDC)

Patent and Copyright Litigation (last 5 years)

Beginning in April 2005 I served as an expert witness in the case of *Power Integrations, Inc. v. Fairchild Semiconductor International, Inc., and Fairchild Semiconductor Corporation,*[1] tried in the U.S. District Court for the District of Delaware, where my participation took the form of Expert Reports, Rebuttals, depositions, and testimony at trial. Beginning in October 2005 I served as an expert witness in the case of *Black & Decker, Inc. v. Robert Bosch Tool Corporation,*[2] tried in the U.S. District Court for the Northern District of Illinois. Eastern Division, where my participation took the form of Expert Reports, depositions, and trial testimony. Beginning in 2006 I served as an expert witness in *Twentieth Century Fox Film Corporation et al. v. Cablevision Systems Corporation et al.,*[3] in the U.S. District Court for the Southern District of New York, where my participation took the form of Expert Reports, depositions, and court testimony. Beginning in April 2009 I served as an expert witness in *United States of America v. Wu et al.,*[4] tried in the U.S. District Court for the District of Massachusetts, where my participation took the form of trial testimony and declarations. Beginning in February 2012 I served as an expert witness in *ABC et al. and WNET et al. v. Aereo Inc.,*[5] in the U.S. District Court for the Southern District of New York, where my participation took the form of Expert Reports, depositions, and court testimony. These cases involve electronic power conversion technologies, worksite radios, remote storage digital video, electronic component technologies, and internet streaming of recorded broadcast video, respectively.

Recent Publications & Conference Proceedings

The Art of Electronics, 3rd edition. with W. Hill. Cambridge University Press, approx 1500 pages (in production, 2012).

"Millions and Billions of Channels." with D. Leigh, chapter in Schuch, H. *Searching for Extraterrestrial Intelligence*, Springer/Praxis (2011).

"Optical SETI." American Association for the Advancement of Science Annual Meeting (2010).

"Robert Vivian Pound" (obituary). *Physics Today* **63** 9, 65 (2010).

"The Planetary Society's All-Sky Optical SETI: Where Are We Now?" *The Planetary Report* **28** 6 (2008).

"Our Place in Space and Time." Getty Center, Los Angeles (2007).

"PulseNet – A Parallel Flash Sampler and Digital Processor IC for Optical SETI." with A. Howard et al., IEEE Custom Integrated Circuits Conference (2006).

"Optical SETI." Royal Astronomical Society, London, (2006).

"Synchronization of the Acoustic Evidence in the Assassination of President Kennedy." with R. Linsker et al., *Science and Justice* **45** 3 (2005).

"Search for nanosecond Optical Pulses from Nearby Solar-type Stars." with A. Howard et al., *Astrophysical Journal* **613** 1270-84 (2004).

"Optical SETI with NASA's Terrestrial Planet Finder." with A Howard, *Icarus* **150** 163–67 (2001).

In addition, author/coauthor of numerous technical reports with restricted publication on topics in national security.

[1] on behalf of Fairchild
[2] on behalf of Bosch
[3] on behalf of Cablevision.
[4] on behalf of Wu et al.
[5] on behalf of Aereo.

Materials Relied Upon

In the preparation of this declaration I have referred to or relied upon the following materials:

• Inspection and operation of a Hopper/Joey at my residence, and comparison with STB-DVRs from DirecTV and Comcast and with DVRs from Panasonic, Mitsubishi, and JVC

• technical and/or promotional materials found at the websites of DISH Network, Slingbox, TiVo, HBO GO, Toshiba, JVC, Sony, Mitsubishi, Panasonic, DirecTV, AT&T, Broadcom, Nielsen, FCC, and other products or services referenced in the declaration.

• block diagrams of Hopper and Joey provided by EchoStar

• the declarations of David Kummer and Dan Minnick submitted in the *Fox* action in the Central District of California, and the transcript of the 7Aug12 deposition of Dan Minnick

• technical documents produced by Dish (DISH 000138–000513)

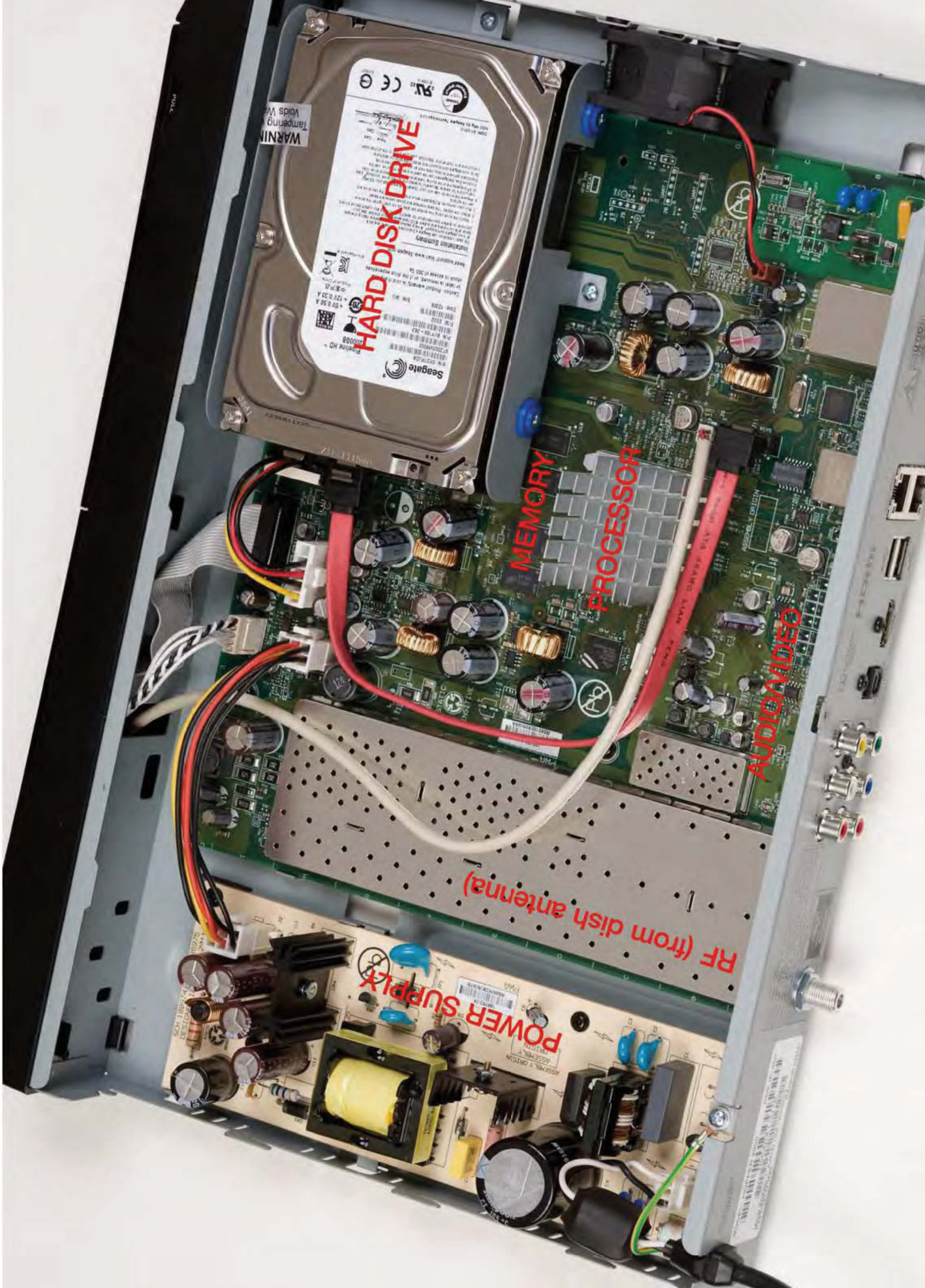
• documents produced by plaintiffs (declarations of Justin Connolly, Thomas Hentoff, Mark Loughney, and Patrick McGovern)

• additional references cited in the declaration

• site visit on 10Dec12 at the EchoStar facilities in Englewood and uplink station in Cheyenne, and technical conversations with some of the EchoStar employees at those locations (Steve Casagrande, Will Beals, Jason Bott, Dennis Davis, Jeff Hladky, Ken Hodge, Cory Link, Ed Petruzelli, and Charlie Zetterower

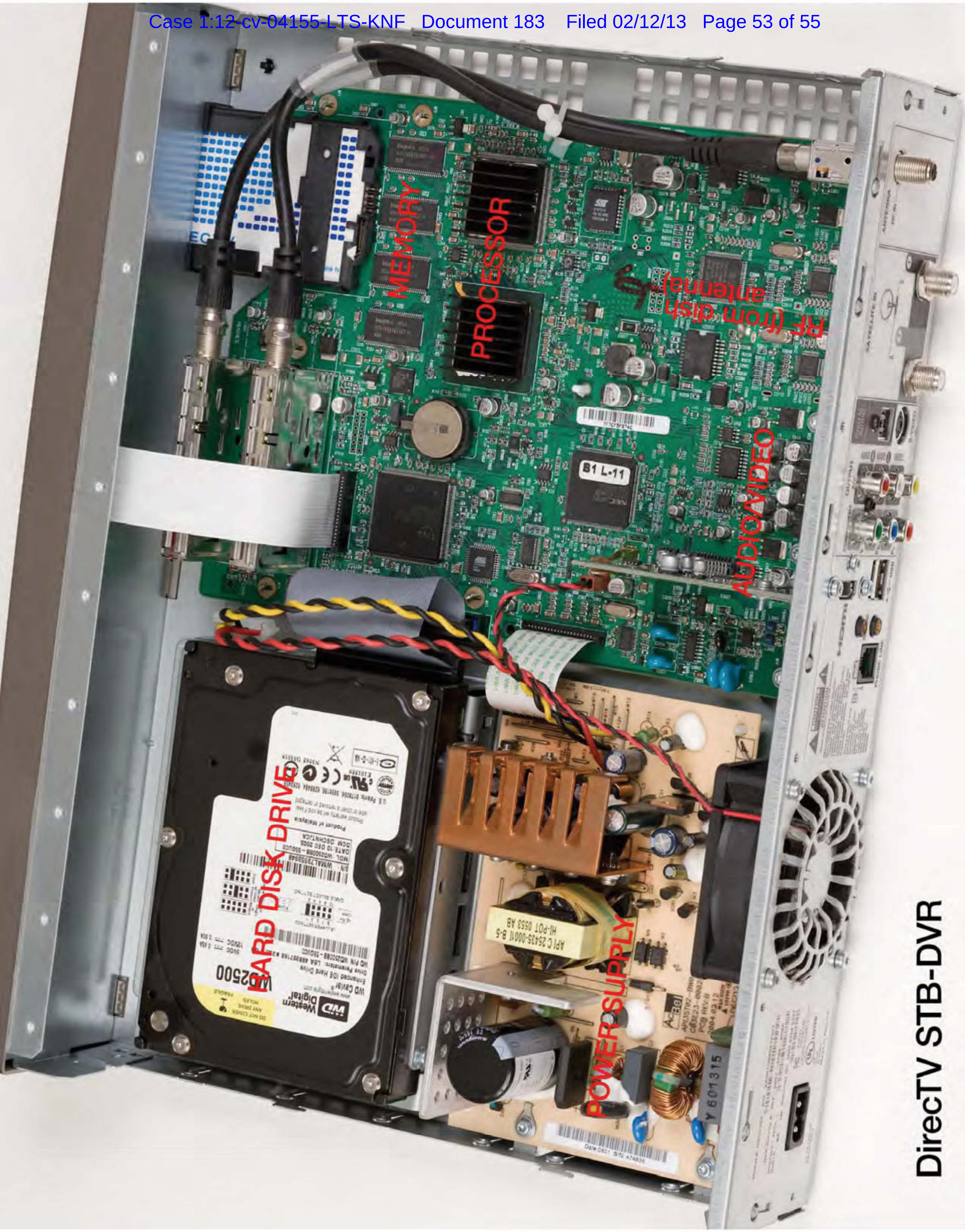
• telephone conversations with Steve Casagrande, Dave Kummer, Dan Minnick, and Mark Templeman

EXHIBIT A



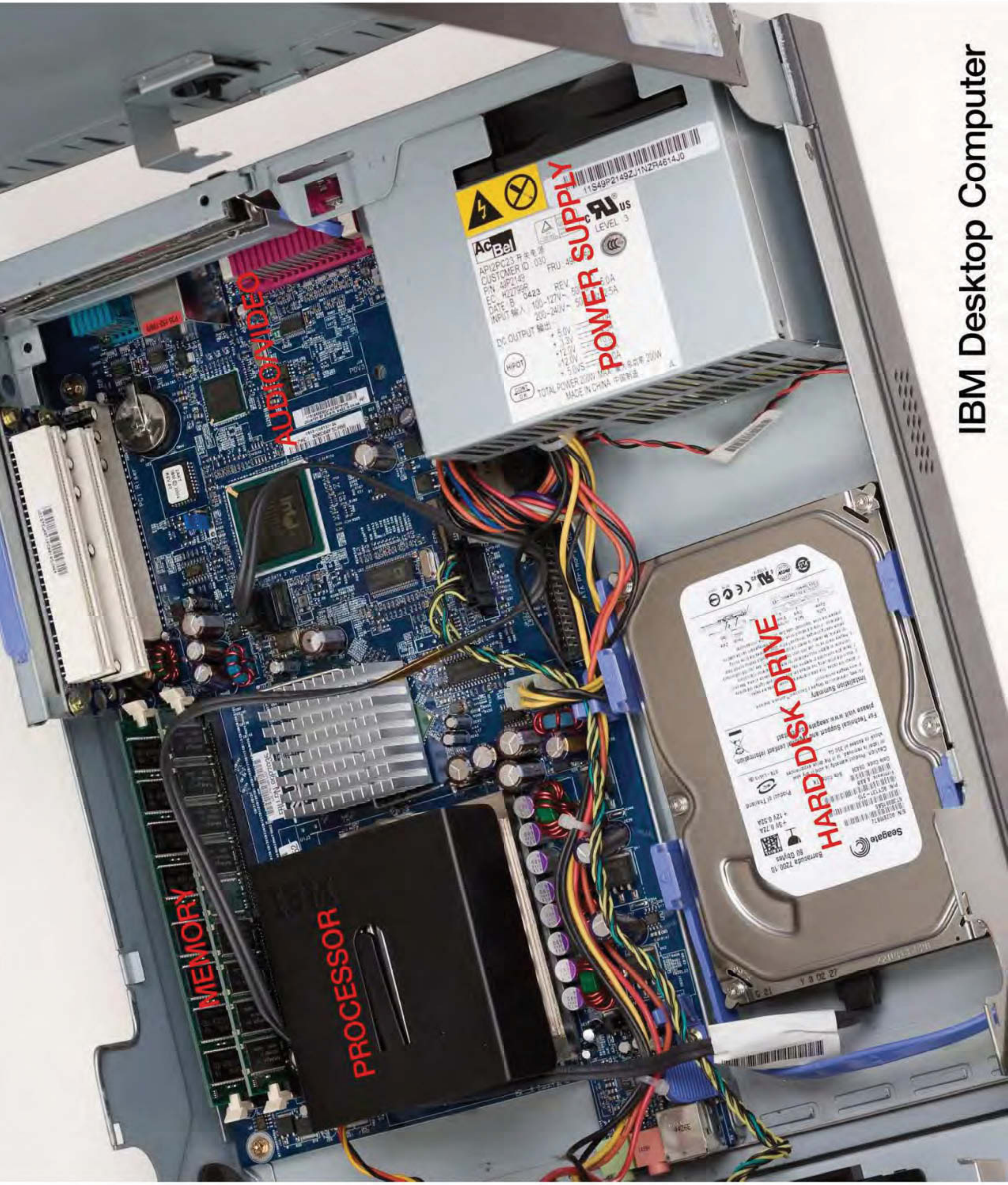
DISH Network Hopper STB-DVR

EXHIBIT B



DirecTV STB-DVR

EXHIBIT C


IBM Desktop Computer
AUDIO/VIDEO
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HARD DISK DRIVE
MEMORY
PROCESSOR